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Meta Analysis: The Effect of Discovery Learning Model on Students' Mathematical Learning Outcomes

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ABSTRACT

The purpose of this study is to determine whether or not there is an effect of discovery learning model on students' mathematical learning outcomes. This research was designed with a review study design that uses meta-analysis techniques by determining the effect size value of each study. The samples used in this study were 10 articles from 2017-2024 at the Elementary School (SD), Junior High School (SMP), and Senior High School (SMA) levels. Based on the results of the analysis, it can be seen that the application of the discovery learning model affects students' mathematical learning outcomes. The results of 10 articles that meet the inclusion criteria, which discuss the effect of the discovery learning model on student mathematical learning outcomes, have an effect size of 0.694 and have an effect on student mathematical learning outcomes. Meanwhile, when viewed from the level of student education, the discovery learning model is most effective if applied because it has an average effect size value at the elementary level with a value of 1.080, the second most effective is applied at the junior high school / MTs level with a value of 0.910, and the third is effective if applied at the SMA / MA / SMK level with a value of 0.324.

Keywords: Discovery Learning, Mathematical learning outcomes, and Meta analysis.

INTRODUCTION

Education is an agent of change that is very important for life. Education is a guideline in building a nation (Nuriah et al., 2023). The quality of a nation can be seen from the field of education. Education can be interpreted as an effort to foster quality and ability in a person. Mathematics is one of the subjects that is very important for children, where mathematics will help students to solve problems that exist in everyday life, and mathematics is a means of thinking logically and clearly (Khotimah & As'ad, 2020). Mathematics is one of the subjects that plays an important role in the world of education (Nafisa & Wardono, 2019). Mathematical ability is an important prerequisite for school performance and career success (Juandi et al., 2020). Mathematical concepts can be obtained from the thinking process, therefore logic is the basis for the formation of mathematics. In 2018 the results of the PISA (Program for International Student Assessment) survey on mathematical literacy scored 379, while in 2022 it scored 366 (Yumnanika & Waluyo, 2023). So it can be interpreted that the mathematical literacy skills of children in Indonesia based on the results of surveys

that have been carried out by PISA (Program for International Student Assessment) are still below the average of the countries participating in the survey. So that there needs to be a solution to the problem. The learning process is a process where an activity between teachers and students
communication so that there is a reciprocal relationship in an educative atmosphere and achieve the desired learning objectives. Mathematics learning at this time, is still teacher-centered. In the learning process, the use of the discovery learning model can make it easier for students to learn and understand the material at school (Azmy and Yustitia, 2021). So that it has an impact, namely increasing students' mathematical learning outcomes.

The discovery learning model is a learning model that is often applied during learning by centering on student activities (A'yun & Maulina, 2023). Discovery learning is one of several learning models recommended in the 2013 Curriculum which refers to Permendikbud No. 103 of 2014 (Khasinah, 2021). When applying the discovery learning model, the teacher only acts as a guide and facilitator who guides students to find concepts, procedures, algorithms, and others. This condition can change the teacher-directed teaching and learning process into student activity. In addition, the discovery learning model offers students the opportunity to become problem solvers or mathematicians (Utami & Jazwinarti, 2019). Discovery learning means learning that involves students in problem solving to develop knowledge and skills (Ermawati et al., 2023). The Discovery Learning model aims to help students learn mathematics to be more active, creative, and innovative (Sekarsari et al., 2023).

The discovery learning model prioritizes active learning, process-related, self-directing, self-finding, and reflective. The discovery learning model must be applied systematically (Khasinah, 2020). It has six stages in the learning process, namely 1). Stimulation or stimulation; 2). Problem statement or problem identification; 3). Data collection or data and information collection; 4). Data processing or data processing; 5). Verification or data analysis and interpretation or also called proof; 6). Generalization or conclusion drawing.

Meanwhile, based on the Ministry of Education and Culture, the discovery learning model generally has two stages. The first stage is preparation. This step is carried out before the learning takes place, namely. when planning implies action, a) determining learning objectives; b) identifying student characteristics, c) choosing topics; d) determining topics that students must learn inductively, e) developing educational materials; f) organizing learning topics from simple to difficult, from concrete to abstract, or from active to symbolic iconic stages; and g) preparing an assessment of the process and results of student learning. Furthermore, the second stage is implementation. This stage is carried out in the implementation of learning, following the five or six steps in the implementation of discovery learning as previously described.

Learning is a process of change related to knowledge, skills, attitudes, and behavior (Suharya, 2021). Every student has a different capacity to learn mathematics (Ardianto et al., 2019). Success in the learning process is influenced by many factors, such as factors from within and factors from outside the learner. learners. Factors from within students are important factors, because the target is students directly. While external factors are encouragement and motivation from others. At present, many students still have difficulty solving problems so that they need the ability to formulate and interpret problems in order to find the right problem-solving strategy (Rahmawati et al., 2023). So that critical thinking skills are needed to improve learning outcomes. Critical thinking skills are examining aspects of the focus of the problem, making connections and evaluating, collecting and organizing information, validating and analyzing

information, remembering and connecting previously learned information, determining rational answers, valid this is the answer (Widodo, 2010). Good learning outcomes are indispensable for both students and teachers at school. But in reality, there are still many students who get little or low scores.

Based on previous research, it shows that Discovery Learning is a learning model that can improve student learning outcomes (Marbun et al., 2022). Many studies of the discovery learning model have a major effect on students' mathematical learning outcomes. So the researcher will conduct research on "Meta Analysis of the Effect of Discovery Learning Model on Students' Mathematical Learning Outcomes". This research uses 10 articles with the same topic, then look for the effect size of each article.

RESEARCH METHODS

This research uses descriptive analytic method with meta-analysis technique. The study analyzed was related to the effect of discovery learning model on students' mathematical learning outcomes. Meta analysis is an assessment of the results of similar studies (Christian, 2021). Meta analysis can also mean that systematic analysis with statistical data to calculate conclusions from several research results from SINTA indexed national journal articles and national proceedings. The purpose of this research is to combine, synthesize, and analyze statistically and systematically (Amelia et al., 2022). So it is necessary to integrate quantitative results in order to draw accurate conclusions and can be useful in policy making (Paloloang et al., 2020).

The data analyzed came from the Google Scholar database (Tamur et al., 2022). The data analysis technique uses effect size (Wahyuni & Astuti, 2021). The meta-analysis question in this study is the effect of the discovery learning model on students' mathematical learning outcomes. This paper uses the PRISMA method (preferred reporting items for systematic review and meta-analysis). The PRISMA protocol is a systematic review method that supports high-quality meta-analysis (Juandi et al., 2022).

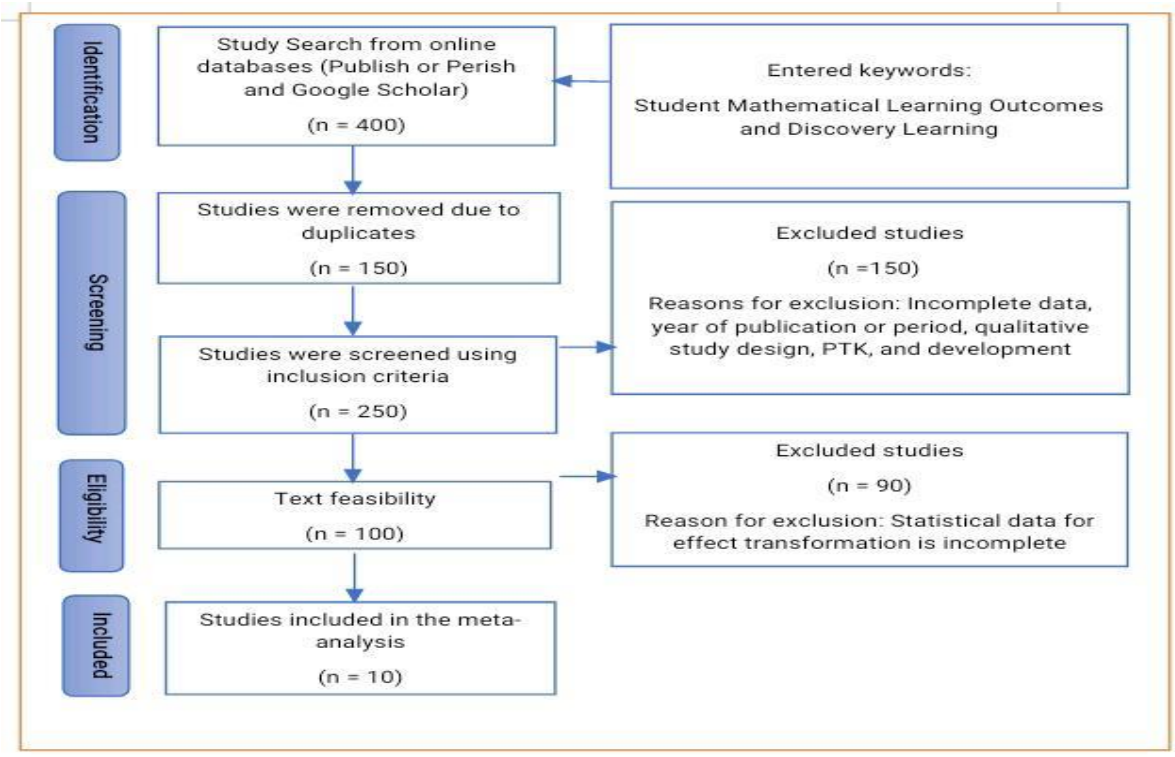

Figure 1. Research procedure using PRISMA method

In addition to the method, inclusion and exclusion criteria are needed which are general characteristics of research subjects from a population according to the research title. The criteria are presented as in table 1 below:

Table 1. Inclusion and Exclusion Criteria

No.	Inclusion Criteria	Exclusion Criteria
1.	SINTA indexed national scientific articles related to the discovery learning model on student mathematical learning outcomes.	Articles that are not full text.
2.	Articles that have a writing time span of the last 7 years or published in the period (2017-2024).	Articles that are not indexed by SINTA.
3.	Articles with experimental or quasi-experimental research methods.	Articles that do not contain statistical data information (mean value, sample size, and standard deviation of the experimental class and control class).
4.	Articles containing statistical data information (mean value, sample size, and standard deviation of the experimental class and control class).	

Data collection was carried out by searching for articles from the SINTA database, Google Scholar, and Publish or Perish to find relevant research articles using the keywords "Discovery Learning Model on Students' Mathematical Learning Outcomes". During the article search process there were 400 relevant titles which were then filtered for research. Then tested for eligibility to be analyzed according to the inclusion criteria resulting in 10 primary studies that can be used in this study.

Furthermore, all data from primary studies will be analyzed and statistically calculated. According to (Wardhani, 2020), meta-analysis can be carried out with the following criteria (1) identifying and determining research problems; (2) collecting data; (3) coding all primary studies that have been determined; (4) conducting statistical analysis (publication bias test, effect size calculation, heterogeneity test, and estimation model, hypothesis testing, study characteristics test); and (5) presentation of research results. All processes in this study were assisted by using OpenMEE software. The following table 2 presents data related to primary studies that will be analyzed in this study.

Table 2. List of articles used in the study

No.	Code	Author	Proceedings/Journals
1.	A01	Sofiroh Febriani, Khamalnah, Lies Diana Pebrianti, dan Indrani Fahminngsih.	Seminar Nasional Pendidikan Matematika, Vol. 1, No. 1, 2020
2.	A02	Septima Br Marbun, Jorry F Monoarfa, dan Derel F. Kaunang.	Jurnal Axioma: Jurnal Matematika dan Pembelajaran. Vol. 7 No. 2., 2022
3.	A03	Fitriyah, Ali Mustadlo, dan Rini Warti.	Jurnal Pelangi. Vol 9 No. 2.,2017
4.	A04	Rindu Widya Eka Putri, Tysa Gustya Manda, dan Maulani Meutia R.	Jurnal Edukasi dan Penelitian Matematika. Vol. 13 No. 1., 2024
5.	A05	Ricky Pramana Setiawan Panie, Nani Kurniati, dan Eka Kurniawan.	Jurnal Ilmiah Profesi Pendidikan. Vol. 8 No. 2., 2023
6.	A06	Muh. Fahrul Nur, Muhammad Muzaini, dan Wahyuddin.	Journal on Education. Vol. 6 No. 1., 2023
7.	A07	Fadisya Ivana Dhea dan Masniladevi.	e-JIPSD: e-Jurnal Inovasi Pembelajaran Sekolah Dasar. Vol. 11 No. 3., 2023
8.	A08	Sutrisno, Nurina Happy, dan Wiwik Susanti.	AKSIOMA: Jurnal Program Studi Pendidikan Matematika. Vol. 9 No. 3., 2020
9.	A09	Mulyadi dan Suci Arimbi.	At-Ta'lim: Jurnal Pendidikan. Vol. 9 No. 2., 2023
10.	A10	Anintya Putri Wahyuni, Abdul Basir Abbas, dan Kukuh.	Jurnal PRIMATIKA. Vol 7 No. 2., 2018

RESULT AND DISCUSSION

After searching and selecting primary studies, 10 articles were obtained that were appropriate and relevant because they met the inclusion criteria that had been determined in this study. The next step is that the entire study from the article is extracted data based on statistical data information and characteristics needed in this study. The results of the data extraction are presented in Table 3.

Table 3. Recapitulation of Data Extraction Results

Statistical Data							
Code	Experiment Group			Control Group			Education Level
	Mean	SD	N	Mean	SD	N	
A01	64,50	20,56	34	61,32	15,93	36	SMA/MA/SMK
A02	78,18	12,00	29	72,74	9,482	23	SMA/MA/SMK
A03	77,94	9,070	32	73,53	8,520	32	SMA/MA/SMK
A04	80,27	9.670	29	67,82	11,52	29	SMP/MTs
A05	58,38	20,49	34	39,85	20,49	34	SMP/MTs
A06	87,50	9.890	24	67,96	23,46	27	SD
A07	80,00	13,07	20	64,77	13,57	22	SD
A08	80,72	7,150	32	74,50	7,150	32	SMP/MTs
A09	58,74	17,05	40	55,50	11,51	40	SMA/MA/SMK
A10	71.80	10.26	36	62.71	12.52	36	SMP/MTs

Table 3 presents information describing data extraction from primary studies whose statistical data are divided into 1 group. That is, there is a group of studies consisting of statistical data on the mean, standard deviation and number of samples, namely studies coded A01, A02, A03, A04, A05, A06, A07, A08, A09, and A10. Furthermore, based on the characteristics of the study at the school education level, it is divided into 3 groups. First, the study group at the elementary school level, namely codes A06, and A07. Second, the study group at the junior high school / MTs level, namely codes A04, A05, A08 and A10. Third, study groups at the senior high school/vocational school level, namely codes A01, A02, A03 and A09. Furthermore, all extracted data were tested for publication bias using funnel plot and fail-safe N (FSN) test. Figure 1 below shows the effect size distribution of each study using the funnel plot.

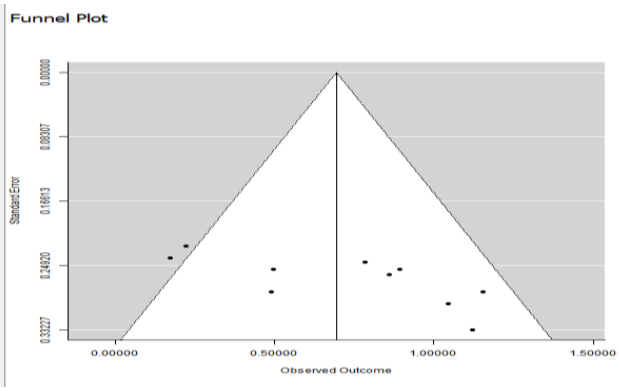

Figure 2. Funnel plot, biased publication test

Figure 2 is a biased publication test conducted using openMEE software. The image can provide information that there are no colorless points or open points in the funnel plot image above and looks asymmetrical. Proving that there are no articles that have publication bias. However, to confirm whether it is valid or not based on these results, another publication bias test can be carried out, namely the fail safe

N test with the results obtained from the openMEE software as follows.

```
OpenMEE build date: 2015-11-15
Summary

Fail-safe N Calculation Using the Rosenthal Approach

Observed Significance Level: <.0001
Target Significance Level:   0.05

Fail-safe N: 247
```

Figure 3. N fail safe test

The fail safe N test is an approach suggested by Rosenthal (1979) with the aim of overcoming the problem of publication bias (Retnawati et al). The figure above shows that the significance level is less than 0.0001 with a target significance of 0.05 and fail safe N = 247. Manually, it can also be calculated using the formula, namely with (5K + 10) substituting the value of N = 247 and K is the number of studies in the meta-analysis is 10, so that the result is 4.1 (more than l), with a significance level of 0.05 and p < 0.0001. It can be interpreted that the data from the 10 primary studies used in this study are included in the analysis that is resistant to publication bias and is suitable for use in further analysis. The criteria used to interpret the effect size results using Cohen's reference (Cohen et al., 2013) are as follows: very low effect (0- 0.20), low effect (0.21 - 0.50), medium effect (0.51 - 1.00), and high effect (> 1.00).

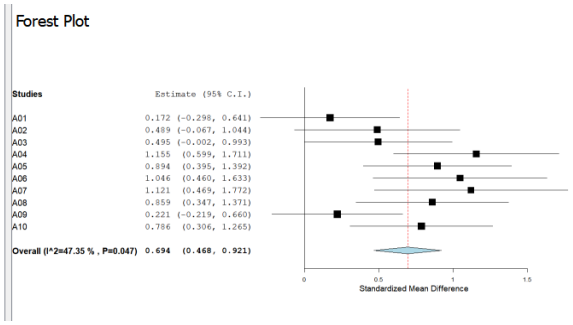

Figure 4. Forest Plot

Based on the resulting output, the effect size is diverse as seen from the distribution in the graph away from the standard rhombus-shaped plot at the very end showing the summary effect of the overall study analyzed with the effect size value obtained, the value is 0.694 which is a medium effect value category.

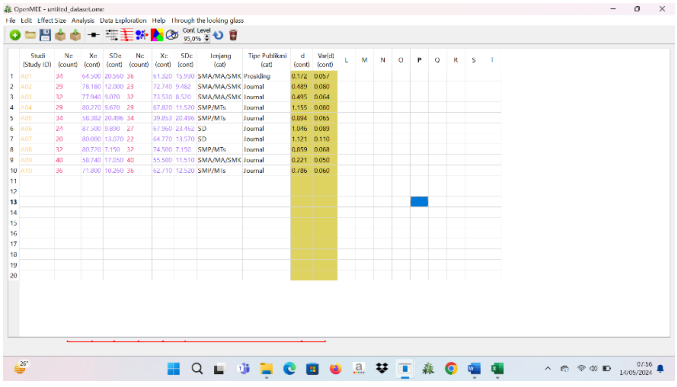

Figure 5: Secondary Study Output Data in OpenMEE Software.

The data display in the figure above shows the effect size of each study based on data input in each study analyzed which contains research results in the form of data on the number of samples (N), Mean or average (X), and Standard Deviation (SD). Furthermore, below is a table showing the effect size values of the 10 articles analyzed in this study based on the forest plot in the figure above.

Table 4. Effect Size Calculation Results

No.	Code	Effect Size	Category	Variant
1.	A01	0.172	Very low	0.057
2.	A02	0.489	Low	0.080
3.	A03	0.495	Low	0.064
4.	A04	1,155	High	0.080
5.	A05	0,894	Medium	0.065
6.	A06	1,046	High	0.089
7.	A07	1.121	High	0.110
8.	A08	0.859	Medium	0.068
9.	A09	0.221	Low	0.050
10.	A10	0.786	Medium	0.060

Table 4 presents the effect size value of each study in a variety of variations, namely, studies with very low effects as much as 1, namely code A01, studies with low effects as much as 3, namely codes A02, A03 and A09, studies with moderate effects as much as 3, namely codes A05, A08 and A10, while studies with high effects as much as 3, namely codes A04, A06, and A07. After this, we conducted a heterogeneity test and determined the estimation model to obtain the overall effect size. The results of the heterogeneity test using openMEE software are as follows.

```
Heterogeneity

tau^2  Q(df=9)   Het. p-Value    I^2

0.062   17.094       0.047      47.35
```

Figure 6: Heterogeneity test

Heterogeneity is the variation of data within each study in this research. Based on the figure in the heterogeneity section, the p-value is 0.047 <0.05 with a significance level of 0.05 and / by 47.35. These results show the diversity of variance of the 10 articles, so the discovery learning model has a significant effect on students' mathematical learning outcomes. This means that the random effect model is considered appropriate to use because the results are heterogeneous. The effect size results with random effect model are presented in the figure below.

```
Summary
Continuous Random-Effects Model

Metric: Standardized Mean Difference

 Model Results

 Estimate  Lower bound   Upper bound   Std. error   p-Value

 0.694        0.468         0.921         0.115     < 0.001
```

Figure 7. Effect size results based on random effect model

Based on Figure 7 random effect model with Hedge's method, it is known that the overall mean effect size value is 0.694 with a lower limit of 0.468, an upper bound of 0.921, and a known standard error of 0.115 and a p-value <0.001 or less than alpha. Indicates that there is a significant difference between the data from the experimental class and the control class. So that the use of the discovery learning model is significant to students' mathematical learning outcomes. It can illustrate that there is a significant contribution or influence of the discovery learning learning model on students' mathematical learning outcomes.

Table 5. Study Characteristics Test Results

Education Level	N	Effect Size	Lower Limit	Upper Limit	Std. Eror	p-value
SMA/MA/SMK	4	0,324	0,081	0,567	0,124	0,009
SMP/MTs	4	0,910	0,655	1,164	0,130	< 0,001
SD	2	1,080	0,644	1,515	0,222	< 0,001

Based on the explanation of the table above, it shows that the effect of the discovery learning model on students' mathematical learning outcomes has an average effect size at the elementary level of 1.080, at the junior high school / MTs level of 0.910, and at the high school / vocational / MA level of 0.324. With a p-value <0.001 at the elementary, junior high school and vocational high school levels.
SMA/MA/ SMK. Thus, the discovery learning model has a significant effect on students' mathematical learning outcomes.

CONCLUSION

The results of 10 primary studies that discuss the effect of the discovery learning model on student mathematical learning outcomes have an effect size of 0.694 and have an effect on student mathematical learning outcomes. Meanwhile, when viewed from the level of student education, the discovery learning model is most effective if applied at the elementary level because it has an average effect size of 1.080, the second most effective is applied at the junior high school / MTs level with a value of 0.910, and the third is effective if applied at the SMA / MA / SMK level with a value of 0.324.
Based on the explanation above, teachers can apply the discovery learning model in learning activities at the elementary, junior high school / MTs, and high school / vocational school levels. So that students' mathematical learning outcomes can improve. For further researchers can add characteristics that will be used such as learning media, learning materials, and others.

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